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Evaluation of risk factors contributing to device-related pressure ulcer development in critically ill patients*

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ABSTRACT

Aims: Device-related pressure ulcers are one of the most common complications observed in patients treated in intensive care units (ICUs). These ulcers negatively impact patient comfort and significantly increase treatment costs. To prevent and manage pressure ulcers caused by medical devices, it is essential to thoroughly understand the associated risk factors. This study aims to determine the prevalence of device-related pressure ulcers in critically ill patients and evaluate the risk factors contributing to their development.

Methods: The study included 91 patients who were monitored with non-invasive mechanical ventilation (NIMV) in the pulmonary intensive care unit between January 1, 2021, and December 31, 2021. The patients' demographic characteristics, nutritional status, body-mass index (BMI), biochemical parameters, and Braden pressure ulcer risk assessment scale scores of the patients were retrospectively analyzed.

Results: The findings revealed no direct relationship between the duration of medical device use and the development of pressure ulcers. However, an increase in the number of days masks were used was significantly associated with the progression of pressure ulcer stages, particularly from early to advanced stages. The study also found that the Braden scoring system was insufficient in predicting pressure ulcers caused by oronasal masks, while patients with higher blood urea nitrogen (BUN) levels tended to have ulcers that remained at early stages without progression. No significant association was found between pressure ulcer development and nutritional status, albumin levels, BMI, or corticosteroid use. However, prolonged ICU stays were associated with the progression of pressure ulcers to more advanced stages.

Conclusion: These results emphasize the importance of optimizing the duration of device usage and selecting appropriate devices to prevent device-related pressure ulcers.

Keywords: Device-related pressure ulcer, non-invasive mechanical ventilation, Braden score, intensive care unit, risk factors

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INTRODUCTION

Pressure ulcers are defined as ischemia, cell death, and tissue necrosis that develop due to prolonged pressure on tissues, typically occurring over areas of bony prominences. Pressure ulcers not only significantly increase treatment and hospitalization costs for inpatients but also greatly reduce patient comfort.[1] Standardizing the diagnosis and staging of pressure ulcers is crucial for treatment monitoring. To this end, staging systems, often recommended by the National pressure injury advisory panel, are commonly used.[2]

The development of pressure ulcers is influenced by certain intrinsic factors related to the patient. Advanced age, smoking, the presence of systemic diseases (such as pulmonary disease, heart disease, diabetes, renal disease), cognitive impairment, high fever, and severe spasticity are all factors that facilitate the development of pressure ulcers.[3] Malnutrition is also recognized as a predisposing factor. Most pressure ulcers are associated with hypoalbuminemia (<3.5 g/dl) due to insufficient nutritional intake. When serum albumin levels fall below 3.5 g/dl, the prevalence of pressure ulcers is approximately 75%, whereas this prevalence drops to 16% when albumin levels exceed this threshold. Additionally, anemia, hypercholesterolemia, dehydration, and deficiencies in ascorbic acid, zinc, calcium, magnesium, vitamin D, and

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vitamin E are other nutritional risk factors for pressure ulcer development.[4]

Moisture caused by incontinence or sweating facilitates skin maceration, making tissues subjected to pressure more prone to necrosis.[5] To assess the risk of pressure ulcer development in intensive care units (ICUs), evaluation scales such as the Braden, Waterlow, and Norton are utilized, with the Braden scale being the most widely used. Studies have shown that patients classified as high-risk according to the Braden scale are more likely to develop pressure ulcers.[6]

Device-related pressure ulcers, which are a core component of diagnosis and treatment, differ from traditional pressure ulcers.[7] In device-related pressure ulcers, lesions typically appear on the skin or mucosa rather than over bony prominences.[8] On the other hand, traditional pressure ulcers usually occur over bony areas and/or tissues exposed to pressure due to immobility or inadequate support surfaces. Device-related pressure ulcers often depend on the position and shape of the medical device. However, the risk factors for both types are similar. Considering the frequent use of medical devices in ICU patients, the risk of pressure ulcers in this group inevitably increases.

In conclusion, there is no ideal or universal method for the prevention and treatment of pressure ulcers. Nevertheless, avoiding risk factors, implementing preventive measures, using support surfaces, applying appropriate dressings, and utilizing specific physical therapy techniques provide physicians and nurses with effective and economical approaches tailored to the patients' needs. Therefore, it is crucial to take the necessary precautions for patients at high risk of developing pressure ulcers and to develop cost-effective and efficient treatment methods after ulcer formation.

In this study, we aim to identify the prevalence of pressure ulcers associated with the use of medical devices (such as BIPAP, CPAP, etc.) in a pulmonary ICU and to highlight related risk factors. In parallel, we intend to discuss potential measures to reduce the incidence of pressure ulcers during subsequent patient follow-ups.

METHODS

Our study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, and approval was obtained from the Clinical Researches Ethics Committee of the University of Health Sciences, Ankara Keçiören Training and Research Hospital (Date: 25.01.2022, Decision No: 2012-KAEK-15/2467). Patients meeting the inclusion and exclusion criteria outlined in the study protocol were retrospectively reviewed and analyzed.

The study included patients who were followed for at least three[3] days on non-invasive mechanical ventilation (NIMV) between January 1, 2021, and December 31, 2021, in the pulmonary intensive care unit of our hospital. In addition to the patients' demographic data, the following parameters were evaluated and recorded: pressure ulcers associated with medical devices (oronasal or nasal masks), comorbidities, duration of device use, body-mass index (BMI), nutritional status, corticosteroid use, and serum biochemical values including blood urea nitrogen (BUN), creatinine, albumin, total protein, sodium, potassium, calcium, magnesium, uric acid, glucose levels, as well as hemogram parameters such as hemoglobin and white blood cell counts.

The Braden pressure ulcer risk assessment scores recorded within the first three days of the patients' ICU admission were collected. Malnutrition risk status was assessed using the Nutritional Risk Screening-2002 (NRS-2002). Over a total follow-up period of 18 days, device-related pressure ulcers and their stages were recorded.

The relationships between pressure ulcers, including their stages, and patients' biochemical and hemogram data, Braden pressure ulcer risk assessment scores, total duration of device use, and nutritional status were analyzed.

Inclusion and Exclusion Criteria

Inclusion criteria:

- Patients aged 18 years or older.
- Patients monitored with an oronasal mask for NIMV for at least 9 days.

Exclusion criteria:

- Patients younger than 18 years.
- Patients who used a mask for NIMV for less than three days.
- Patients who died within the first 9 days of hospitalization.
- Patients discharged before 9 days.
- Patients who did not sign the informed consent form.

Use of Oro-Nasal Masks in Patients

In our clinic, NIMV devices are utilized for patients with type 2 respiratory failure. When using these devices, oro-nasal masks are preferred as the first choice to minimize anatomical dead space, enhance patient compliance, and prevent feelings of claustrophobia. While nasal masks are unsuitable for patients who predominantly breathe through their mouths, full-face masks are not preferred as the first choice in our clinic due to their tendency to increase both anatomical dead space and claustrophobic sensations.

To enhance the effectiveness of NIMV and maintain leakage rates below 50%, specific measures are implemented when applying oro-nasal masks. These include shaving beards in male patients before mask application, ensuring that gastric tubes in patients with nasogastric tubes remain clamped within the mask, and securing the mask straps with adequate tightness. These precautions were applied to all patients included in the study.

Braden Pressure Ulcer Risk Assessment Scale

The Braden pressure ulcer risk assessment scale, developed by Braden and Bergstrom[9], underwent its first reliability and validity study in Turkey by Oğuz in 1997. In 1998, Pınar and Oğuz[10] further examined the reliability and validity of the Norton and Braden Risk Assessment Scales, finding both to have high reliability and validity.

The scale consists of six subscales: sensory perception, moisture, activity, mobility, nutrition, and friction/shear. The total score, ranging from 6 to 23, is obtained by summing the scores of the subscales (Table 1). Based on the total score:

- A score of 12 or lower indicates a high risk.
- A score of 13–14 indicates a moderate risk.
- A score of 15–16 indicates a low risk.
- For individuals over 75 years of age, a score of 15–18 is also considered a low risk.[11]

Statistical Analysis

IBM SPSS (Statistical Package for the Social Sciences) Statistics, Version 27 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Categorical (nominal) data were presented as n (%) values. Ordinal data or numerical data that did not follow normal distribution were presented as median (min-max), whereas numerical data that followed a normal distribution were presented as mean (SD).

For categorical variables, the chi-square test was used if each cell had more than five cases. If at least one cell had fewer than five cases, Fisher's exact test was applied. For comparisons of categorical variables with more than two categories, the likelihood ratio test was employed when at least one cell contained fewer than five cases in the cross-tabulation.

Numerical data were analyzed using the Student's t-test if they exhibited a normal distribution, and the Mann-Whitney U test if they did not. For comparisons involving numerical variables with more than two categories, one-way ANOVA was used for normally distributed data, and the Kruskal-Wallis H test was applied for non-normally distributed data.

The normality of numerical data was assessed using descriptive statistics, including Kolmogorov-Smirnov and Shapiro-Wilk tests, skewness-kurtosis values, histograms, and an evaluation of the proximity of outliers. If a significant difference was observed between group means for normally distributed numerical variables, effect size was calculated using Cohen's d value.

A 95% confidence interval was used for all analyses, and statistical significance was set at $p<0.05$.

RESULTS

The data from a total of 91 patients meeting the inclusion criteria of the study were analyzed. The mean age of the patients was calculated to be 66.8±8 years. Of the patients, 62.6% (n=57) were male, and 37.4% (n=34) were female.

Pressure ulcers caused by the use of oronasal masks for NIMV were classified based on their severity on the third, sixth, and ninth days of hospitalization as follows:

- **Stage 0:** No ulcer.
- **Stage 1:** Redness.
- **Stage 2:** Disruption of skin integrity.
- **Stage 3:** Ulcer involving all layers of the skin.
- **Stage 4:** Ulcer causing tissue loss.

Additionally, Braden pressure ulcer risk scores were recorded for all patients within the first three days of hospitalization. Nutritional status was assessed using NRS-2002 scores at the time of admission. All other variables mentioned in the "materials and methods" section were also analyzed.

PRESSURE ULCER STATUS ON DAY 3

At this stage of the study, 10 out of 91 patients (10.9%) had not yet developed device-related pressure ulcers, while 81 out of 91 patients (89.1%) had developed stage 1 pressure ulcers.

No significant differences were found between the groups with and without pressure ulcers in terms of the following parameters measured at ICU admission: hemoglobin, hematocrit, albumin, sodium, potassium, calcium, glucose, white blood cell count, neutrophil count, creatinine, BUN, and uric acid levels.

Similarly, there were no significant differences between the two groups regarding BMI, the number of days corticosteroids were used, total corticosteroid dosage, daily corticosteroid dosage, the number of hours masks were used daily, or the total number of days masks were used (Table 2).

Additionally, no significant differences were observed between the groups with and without pressure ulcers on the third day in terms of the presence of diabetes mellitus (DM), hypertension (HT), heart failure, or pneumonia. No significant associations were found based on gender, ICU admission source, or Braden risk score categories (Table 2).

Pressure Ulcer Status on Day 6

By the sixth day of the study, 8 out of 91 patients (8.7%) had not developed pressure ulcers, while 62 out of 91 patients (68.2%) had stage 1 pressure ulcers and 21 out of 91 patients (23.1%) had stage 2 pressure ulcers.

The results of one-way ANOVA and Kruskal-Wallis H tests showed no significant differences among these three groups (no ulcer, stage 1, and stage 2) in terms of hemoglobin, hematocrit,

Table 1. Braden pressure ulcer risk assessment scale

Subparameters	Point: 1	Point: 2	Point: 3	Point :4
Sensory perception	Completely limited	Very limited	Slightly limited	No impairment
Moisture	Constantly moist	Very moist	Occasionally moist	Rarely moist
Aktivity	Bedbound	Chairbound	Walk occasionaly	Walks frequently
Mobility	Completely immobile	Very limited	Slightly limited	No limitations
Nutrition	Very poor	Probably inadequate	Adequate	Excellent
Friction and shear	Problem	Potential problem	No apparent problem	No problem

Table 2. Analysis of data according to device-related pressure ulcer status on the third day

Variable	Pressure ulcer non-developing group mean±sd, median (min-max), n (%)				Pressure sore developing (Stage 1) mean±sd, median (min-max), n (%)				p value
Hemoglobin (g/dl)	13.76±2.25				13.30±2.45				0.577[a]
Hematocrit (%)	45.76±8.51				43.10±8.06				0.331[a]
Glucose (mg/dl)	133.5 (72.0–285.0)				136.0 (72.0–675.0)				0.934[b]
WBC (/µl)	8550 (4670–11070)				9350 (2930–38560)				0.542[b]
Creatinine (mg/dl)	1.14 (0.53–1.75)				0.87 (0.08–1.8)				0.238[b]
BUN (mg/dl)	30.0 (9.0–49.0)				22.0 (8.0–65.0)				0.064[b]
Uric acid (mg/dl)	7.05 (5.5–12.0)				5.6 (2.0–18.07)				0.050[b]
Albumin (g/dl)	3.38±0.44				3.42±0.45				0.771[a]
Sodium (mmol/l)	141.0±4.47				139.08±4.99				0.281[a]
Calcium (mg/dl)	9.01±0.78				8.83±0.58				0.382[a]
Potassium (mmol/l)	4.67±0.82				4.56±0.56				0.599[a]
Number of mask days	10.0 (3.0–11.0)				8.0 (3.0–34.0)				0.899[b]
Daily mask duration	10.0 (6.0–12.0)				10.0 (4.0–22.0)				0.119[b]
Steroid daily dose (methylprednisolone) (mg)	0.0 (0.0–40.0)				26.0 (0.0–135.0)				0.402[b]
Total steroid dose (methylprednisolone) (mg)	0.0 (0.0–320.0)				80.0 (0.0–960.0)				0.462[b]
Number of days steroid applied	0.0 (0.0–9.0)				2.0 (0.0–30.0)				0.482[b]
BMI (kg/m^2)	26.7 (20.44–37.11)				26.12 (15.94–67.75)				0.643[b]
NRS-2002	3.5 (3.0–5.0)				4.0 (3.0–7.0)				0.463[b]
Braden score	20 (10-22)				18 (10-22)				0.282[b]
DM	Yes: 2 (20%)		No: 8 (80%)		Yes: 23 (28.4%)		No: 58 (71.6%)		0.721[c]
HT	Yes: 2 (20%)		No: 8 (80%)		Yes: 13 (16%)		No: 68 (84%)		0.667[c]
Heart failure	Yes: 1 (10%)		No: 9 (90%)		Yes: 5 (6.2%)		No: 76 (93.8%)		0.513[c]
Gender	Male: 4 (40%)		Female: 6 (60%)		Male: 53 (65.4%)		Female: 28 (34.6%)		0.166[c]
Pneumonia	Yes: 0 (0%)		No: 10 (100%)		Yes: 11 (13.6%)		No: 70 (86.4%)		0.603[c]
Place of admission to ICU	Emergency sevice: 7 (70%)	Other department: 1 (10%)	Other ICU: 2 (20%)		Emergency sevice: 45 (55.6%)	Other department: 13 (16%)	Other ICU: 23 (28.4%)		0.672[d]
Braden risk category	A: 6 (60%)	B: 3 (30%)	C: 0 (0%)	D: 1 (10%)	A: 36 (44.4%)	B: 36 (44.4%)	C: 4 (4.9%)	D: 5 (6.2%)	0.569[d]

a Student t test, b Mann-Whitney U testi, c Fisher exact, d Likelihood ratio, BUN: Blood urea nitrogen, DM: Diabetes mellitus, HT: Hypertension, ICU: Intensive care unit, NRS: Nutritional risk score, BMI: Body-mass index, YB: Intensive care, A: Risk-free, B: Low risk, C: Risky, D: High risk

albumin, sodium, potassium, calcium, glucose, white blood cell count, creatinine, uric acid, and neutrophil levels (Table 3). Similarly, there were no significant differences in BMI, the number of days corticosteroids were used, total corticosteroid dosage, daily corticosteroid dosage, the number of hours masks were used daily, Braden scores (both at admission and the sixth day), or NRS-2002 scores among the groups.

Significant Findings

BUN levels: A significant difference in BUN values was observed among the three groups (p=0.033). Pairwise comparisons revealed that patients without ulcers had significantly higher BUN levels compared to those with stage 1 ulcers (p=0.018). However, no significant difference was found in BUN values between patients with stage 1 and stage 2 ulcers (Table 3).

Duration of mask use: A significant difference was also identified in the number of days masks were used among the groups (p=0.021). Pairwise comparisons showed no significant difference between patients without ulcers and those with stage 1 ulcers. However, patients with stage 2 ulcers had a significantly longer duration of mask use compared to those with stage 1 ulcers (p=0.006) (Table 3).

Other Findings

No significant differences were found among the groups in terms of the presence of DM, HT, or pneumonia. Additionally, there were no significant associations based on gender, ICU admission source, or Braden risk score categories (Table 3).

Pressure Ulcer Status on Day 9

By the ninth day of the study, the distribution of patients across pressure ulcer stages was as follows:

- No ulcer**:** 8 patients (8.7%).
- Stage 1: 58 patients (63.7%).
- Stage 2**:** 22 patients (24.1%).
- Stage 3**:** 3 patients (3.2%).

Table 3. Analysis of data according to device-related pressure ulcer status on the sixth day

Variable	Pressure ulcer non-developing group mean±SD, median (min-max), n (%)	Pressure sore developing (stage 1) mean±SD, median (min-max), n (%)	Pressure sore developing (stage 2) mean±SD, median (min-max), n (%)	p value
Hemoglobin (g/dl)	13.3±0.7	13.2±0.3	13.7±0.4	0.683[e]
Hematocrit (%)	43.9±2.1	42.6±1.1	45.4±1.4	0.397[e]
Glucose (mg/dl)	148 (102-285)	132 (72-418)	138 (79-675)	0.628[f]
WBC (/µl)	9140 (4670-11070)	9175 (2930-38560)	9950 (6740-17460)	0.302[f]
Serum creatinine (mg/dl)	1.21 (0.69-1.75)	0.84 (0.8-1.8)	0.92 (0.57-1.47)	0.096[f]
BUN (mg/dl)	32 (19-49)	22.5 (8-65)	18 (13-38)	**0.033**[f*]
Uric acid (mg/dl)	6.9 (5.5-12)	5.6 (2-18.07)	6.1 (2.3-11.7)	0.186[f]
Albumin (g/dl)	3.3±0.11	3.4±0.05	3.49±0.1	0.718[e]
Sodium (mmol/l)	140.6±1.7	139±0.66	139.5±0.94	0.669[e]
Calcium (mg/dl)	8.9±0.16	8.8±0.07	8.7±0.13	0.492[e]
Potassium (mmol/l)	4.6±0.22	4.4±0.07	4.7±0.11	0.183[e]
Number of mask days	10 (3-11)	7 (3-34)	9 (7-30)	0.021[f]
Daily mask duration	10 (6-12)	10 (6-22)	10 (4-16)	0.902[f]
Steroid daily dose (methylprednisolone) (mg)	0 (0-40)	28 (0-125)	0 (0-135)	0.126[f]
Total steroid dose (methylprednisolone) (mg)	0 (0-320)	80 (0-960)	0 (0-540)	0.796[f]
Number of days steroid applied	0 (0-9)	3 (0-30)	0 (0-17)	0.915[f]
BMI (kg/m^2)	26.4 (20.4-37.1)	26.1 (15.9-67.7)	26.1 (17.7-41.9)	0.991[f]
NRS-2002	3 (3-5)	4 (3-7)	4 (3-6)	0.348[f]
Braden score	20 (10-22)	18 (10-22)	17(12-22)	0.563[f]
DM	Yes: 2 (25%) / No: 6 (75%)	Yes: 19 (30.6%) / No:43 (69.4%)	Yes: 4 (19%) / No: 17 (81%)	0.566[d]
HT	Yes: 2 (25%) / No: 6 (75%)	Yes: 7 (11.3%) / No: 55 (88.7%)	Yes: 6 (28.6%) / No: 15 (71.4%)	0.163[d]
Heart failure	Yes: 1 (12.5%) / No: 7 (87.5%)	Yes: 4 (6.5%) / No: 58 (93.5%)	Yes: 1 (4.8%) / No: 20 (95.2%)	0.782[d]
Gender	Female: 4 (50%) / Male: 4 (50%)	Female: 23 (37.1%) / Male: 39 (62.9%)	Female: 7 (33.3%) / Male:14 (66.7%)	0.712[d]
Pneumonia	Yes :0 (0%) / None: 8 (100%)	Yes: 7 (11.3%) / None: 55 (88.7%)	Yes: 4 (19%) / None: 17 (83%)	0.231[d]
Place of admission to ICU	Emergency service : 5 (62.5%) / Other department: 1 (12.5%) / Other ICU: 2 (25%)	Emergency service: 37 (59.7%) / Other department: 9 (14.5%) / Other ICU: 16 (25.8%)	Emergency service: 10 (47.6%) / Other department: 4 (19%) / Other ICU: 7 (33.3%)	0.904[d]
Braden risk category	A: 5(62.5%) / B: 2 (25%) / C: 0 (0%) / D: 1 (12.5%)	A: 27 (43.5%) / B: 31 (50%) / C: 1 (1.6%) / D: 3(4.8%)	A: 10 (47.6%) / B: 6 (28.6%) / C: 3 (14.3%) / D: 2(9.5%)	0.173[d]

d Likelihood ratio, e One way anova, f Kruskal-Wallis H test, SD: Standard deviation, BUN: Blood urea nitrogen, DM: Diabetes mellitus, HT: Hypertension, ICU: Intensive care unit, NRS: Nutritional Risk Score, BMI: Body-mass index, A: Risk-free, B: Low risk, C: Risky, D: High risk

Statistical analysis using one-way ANOVA and Kruskal-Wallis H tests revealed no significant differences among these four groups in terms of hemoglobin, hematocrit, albumin, sodium, potassium, calcium, glucose, white blood cell count, creatinine, uric acid, BUN, and neutrophil levels (Table 4). Similarly, no significant differences were observed for BMI, the number of days corticosteroids were used, total corticosteroid dosage, daily corticosteroid dosage, the number of hours masks were used daily, Braden scores, Braden scores measured on the ninth day, or NRS-2002 scores among the groups (Table 4).

Significant Findings

Duration of mask use: A significant difference was observed in the number of days masks were used among the groups (p=0.003). Pairwise comparisons: No significant difference was found between patients without ulcers and those with stage 1 ulcers. Patients with stage 2 ulcers had a significantly longer duration of mask use compared to those with stage 1 ulcers (p=0.001). While patients with stage 3 ulcers had a longer duration of mask use than those with stage 2 ulcers, this difference was not statistically significant.

Length of ICU stay: A significant difference was also found in the length of ICU stay among the groups (p=0.016).

Pairwise comparisons: No significant difference was found between patients without ulcers and those with stage 1 ulcers, or between stage 1 and stage 2 ulcer groups. However, patients with stage 3 ulcers had a significantly longer ICU stay compared to those with stage 2 ulcers (p=0.027).

Table 4. Analysis of data according to device-related pressure ulcer status on the ninth day

Variable	Pressure ulcer non-developing group mean±SD, median (min-max), n (%)	Pressure sore developing (stage 1) mean±SD, median (min-max), n (%)	Pressure sore developing (stage 2) mean±SD, median (min-max), n (%)	Pressure sore developing (stage 3) mean±SD, median (min-max), n (%)	p value
Hemoglobin (g/dl)	13.3±0.7	13.1±0.3	13.7±0.4	15.2±1.5	0.412[e]
Hematocrit (%)	43.9±2.1	42.4±1.1	44.8±1.3	49.9±4.5	0.319[e]
Glucose (mg/dl)	148 (102-285)	132 (72-418)	138 (79-675)	92 (88-127)	0.260[f]
WBC (/µl)	9140 (4670-11070)	9175 (2930-38560)	9820 (5540-19380)	9270 (6780-12580)	0.598[f]
Serum creatinine (mg/dl)	1.2 (0.69-1.75)	0.83 (0.8-1.8)	0.93 (0.58-1.65)	0.8 (0.57-1)	0.114[f]
BUN (mg/dl)	32 (19-49)	22 (8-58)	20 (13-65)	20 (18-26)	0.087[f]
Uric acid (mg/dl)	6.9 (5.5-12)	5.6 (2-11.9)	6.1 (2.3-18.7)	4.8 (4.7-11.7)	0.332[f]
Albumin (g/dl)	3.3±0.11	3.3±0.05	3.5±0.1	3.4±0.2	0.736[e]
Sodium (mmol/l)	140.6±1.7	139±0.6	139.3±1	139.6±1.7	0.873[e]
Calcium (mg/dl)	8.9±0.1	8.8±0.08	8.7±0.12	8.5±0.13	0.584[e]
Potassium (mmol/l)	4.6±0.2	4.4±0.07	4.7±0.11	4.3±0.3	0.227[e]
Number of mask days	10 (3-11)	7 (3-34)	9 (7-30)	15 (14-15)	***0.003***[f*]
Daily mask duration	10 (6-12)	10 (6-22)	10 (4-16)	12 (10-12)	0.292[f]
Steroid daily dose (methylprednisolone) (mg)	0 (0-40)	28 (0-125)	0 (0-135)	28 (0-31)	0.192[f]
Total steroid dose (methylprednisolone) (mg)	0 (0-320)	80 (0-960)	0 (80-540)	200 (0-380)	0.536[f]
Number of days steroid applied	0 (0-9)	3 (0-30)	0 (0-17)	7 (0-12)	0.648[f]
BMI (kg/m^2)	26.4 (20.4-37.1)	25.8 (16.6-67.7)	26.8 (15.9-54.6)	24.4 (22.9-29.1)	0.928[f]
NRS-2002	3 (3-5)	4 (3-7)	4 (3-6)	4 (4-4)	0.619[f]
Braden score	20 (10-22)	18 (10-22)	18 (12-22)	16 (12-21)	0.679[f]
DM	Yes: 2 (25%) / No: 6 (75%)	Yes: 19 (32.8%) / No: 39 (67.2%)	Yes: 4 (18.2%) / No: 18 (581.8)	Yes: 0 (0%) / No: 3 (100%)	0.287[d]
HT	Yes: 2 (25%) / No: 6 (75%)	Yes: 5 (8.6%) / No: 53 (91.4%)	Yes: 7 (31.8%) / No: 15 (68.2%)	Yes: 1 (33.3%) / No: 2 (66.7%)	0.07[d]
Heart failure	Yes: 1 (12.5%) / No: 7 (87.5%)	Yes: 3 (5.2%) / No: 55 (94.8%)	Yes: 2 (9.1%) / No: 20 (90.9%)	Yes: 0 (0%) / No: 3 (100%)	0.758[d]
Gender	Female: 4 (50%) / Male: 4 (50%)	Female: 22 (37.9%) / Male: 36 (62.1%)	Female: 7 (31.8%) / Male: 15 (68.2%)	Female: 1 (33.3%) / Male: 2 (66.7%)	0.837[d]
Pneumonia	Yes: 0 (0%) / No: 8 (100%)	Yes: 7 (12.1%) / No: 51 (87.9%)	Yes :4 (18.2%) / No: 18 (81.8%)	Yes: 0 (0%) / No: 3 (100%)	0.319[d]
Place of Admission to ICU	Emergency service: 5 (62.5%) / Other department: 1 (12.5%) / Other ICU: 2 (25%)	Emergency service: 35 (60.3%) / Other department: 8 (13.8%) / Other ICU: 15 (25.9%)	Emergency service: 10 (45.5%) / Other department: 5 (22.7%) / Other ICU: 7 (31.8%)	Emergency service: 2 (66.7%) / Other department: 0 (0%) / Other ICU: 1 (33.3%)	0.840[d]
Braden risk category	A: 5 (62.5%) / B: 2 (25%) / C: 0 (0%) / D: 1 (12.5%)	A: 26 (44.8%) / B: 28 (48.3%) / C: 1 (1.7%) / D: 3 (5.2%)	A: 10 (45.5%) / B: 8 (36.4%) / C: 3 (13.6%) / D: 1 (4.5%)	A: 1 (33.3%) / B: 1 (33.3%) / C: 0 (0%) / D: 1 (33.3%)	0.421[d]

d Likelihood ratio, e One way anova, f Kruskal-Wallis H testi, SD: Standard deviation, BUN: Blood urea nitrogen, DM: Diabetes mellitus, HT: Hypertension, ICU: Intensive care unit, NRS: Nutritional Risk Score, BMI: Body-mass index, A: Risk-free, B: Low risk, C: Risky, D: High risk

Other Findings

No significant differences were observed among the groups in terms of the presence of DM, HT, or pneumonia. Additionally, no significant associations were found based on gender, ICU admission source, or Braden risk score categories (Table 4).

DISCUSSION

In this study, we aimed to analyze the development of pressure ulcers caused by oronasal masks used for NIMV in respiratory ICUs. We evaluated this in relation to variables such as patients' nutritional and inflammatory status (as reflected by admission blood values), BMI, the use of corticosteroids (commonly administered in respiratory ICUs), and the presence of certain clinical conditions, which we hypothesized could influence the development of pressure ulcers on the nose and surrounding tissues.

The predictive value of pressure ulcer risk assessment tools in bedridden patients has been demonstrated in previous studies.[6,12] However, no studies were found in the literature that specifically evaluated the effectiveness of oronasal masks used for NIMV in predicting pressure ulcer development. A multicenter study conducted in Iran reported that low Braden risk score averages for nasal oxygen tubes, oxygen face masks, and endotracheal tubes were significantly associated with an increased risk of ulcer development.[13] In our study, we compared Braden scores both as numerical values and

using the categories defined in the literature[11] among patients who developed ulcers at different stages and those who did not. However, we found no statistically significant results, leading us to conclude that the Braden risk assessment system is ineffective in predicting pressure ulcers caused by oronasal masks used for NIMV.

Key Findings

One of the most critical findings of our study was that while the daily duration of mask use did not significantly influence the development of pressure ulcers, the number of days masks were used was a significant factor. Starting from the sixth day, patients with stage 1 pressure ulcers showed a significantly higher risk of progression to stage 2 ulcers as the number of days of mask use increased. This trend continued on the ninth day. Similarly, a study by Ferrari et al.[14] which analyzed risk factors for device-related pressure ulcers in patients using NIMV, found that the use of oronasal masks, the duration of ventilation, the type of nutritional support, and chronic corticosteroid use were associated with ulcer development. However, in our study, no relationship was found between the number of corticosteroid use days, daily dosage, or total dosage and pressure ulcer development. We did, however, identify the number of days masks were used as a risk factor for ulcer progression from redness (stage 0>>stage 1) to ulcer formation (stage 1>>stage 2). Visscher et al.[15] emphasized the importance of proper mask selection and moisturizing the skin to prevent such developments.

Nutritional status, albumin levels, and BMI values in our patients were not associated with device-related pressure ulcer development. In the literature, both high and low BMI values have been identified as risk factors for pressure ulcer development.[16,17] Additionally, low albumin levels and malnutrition are recognized as risk factors.[16] A study by Chen et al.[18] described a "U-shaped" relationship between BMI and pressure ulcer risk, indicating that both high and low BMI values pose a risk.

Another significant finding was the length of ICU stay. Patients who stayed longer in the ICU were significantly more likely to have their ulcers progress to stage 3. This raises a potential paradox: do longer ICU stays increase the risk of pressure ulcers, or do pressure ulcers prolong ICU stays? Many studies have emphasized that pressure ulcers significantly extend ICU stays.[19,20] However, our study specifically focused on oronasal masks, and our patients already had ICU stays prior to mask use. It is possible that patients with longer ICU stays had more comorbidities, which worsened their ulcers.

Lastly, we observed that patients with stage 1 ulcers had significantly lower BUN levels compared to those without ulcers. A study conducted in a surgical ICU reported significantly higher BUN/creatinine ratios in patients with pressure ulcers.[21] Another study suggested two perspectives on high BUN levels: they may either indicate reduced vasodilatory mediators from the kidney, delaying wound healing and increasing ulcer risk, or they may reflect good nutritional status.[22] In our study, we associated high BUN levels with good nutrition. Moreover, the median and minimum-maximum BUN values of our patients indicate that none had BUN levels suggestive of acute or chronic renal dysfunction. Although we found that higher BUN levels were associated with fewer device-related pressure ulcers in our study, future research with a larger patient cohort and higher BUN levels is necessary to determine whether similar results can be reproduced. To achieve more robust and realistic findings, patients could be stratified into quartiles based on BUN levels, allowing for a comparative analysis of four distinct patient groups. Statistical analyses conducted using this approach may reveal a U-shaped relationship, where both extremely high and extremely low BUN levels are associated with an increased risk of pressure ulcers, thereby potentially supporting both our findings and the existing literature.

Limitations

The limitations of our study include the relatively small sample size, primarily due to the exclusion of patients discharged before the required follow-up period. Additionally, the retrospective design, single-center setting, and focus on a single type of medical device limit the generalizability of our findings.

CONCLUSION

We believe that the three valuable and significant findings of our study should be considered during the follow-up processes of patients undergoing NIMV with an oronasal mask due to respiratory failure. Based on the data indicating that pressure ulcers improved in patients with moderately elevated BUN levels, reflecting a positive nitrogen balance, we recommend a protein-rich diet to both prevent the development of pressure ulcers and improve respiratory functions. Furthermore, to reduce device-related pressure ulcers, we emphasize the importance of minimizing the number of days patients use the mask and avoiding unnecessary prolongation of hospital stays during NIMV treatment.

ETHICAL DECLARATIONS

Ethics Committee Approval

Approval was obtained from the Clinical Researches Ethics Committee of the University of Health Sciences, Ankara Keçiören Training and Research Hospital (Date: 25.01.2022, Decision No: 2012-KAEK-15/2467).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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